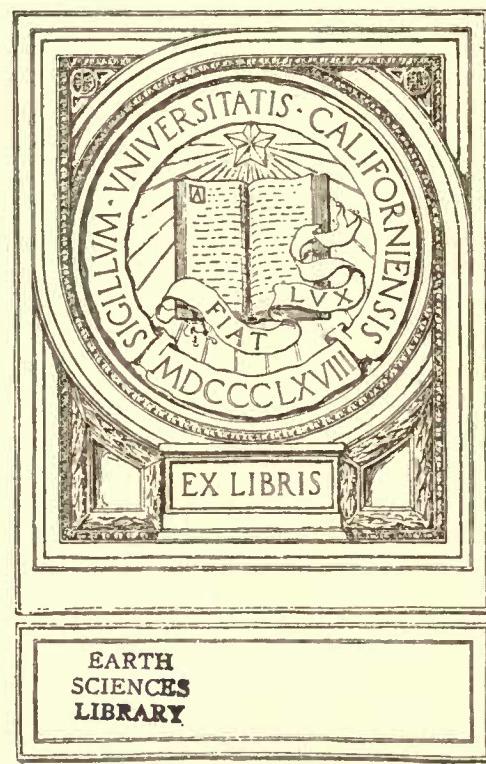


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**VARIOUS PAPERS
ON THE PROJECTED COOPERATION
WITH ROALD AMUNDSEN'S NORTH
POLAR EXPEDITION**



KRISTIANIA 1920 :: GRØNDahl & SØNS BOKTRYKKERI
I KOMMISSION HOS CAMMERMEYERS BOGHANDEL

VARIOUS PAPERS
ON
THE PROJECTED CO-OPERATION WITH
ROALD AMUNDSEN'S NORTH POLAR EXPEDITION

W. H. D. 21 Oct 1861

Dear Sirs, I have the pleasure to inform you that we have
arrived at our destination, and are now in good health.

ON THE PROJECTED CO-OPERATION WITH ROALD AMUNDSEN'S NORTH POLAR EXPEDITION

BY

TH. HESSELBERG

When in June 1918 Roald Amundsen started his expedition, the war was still going on. Therefore it was not possible to organize any co-operation like that which was planned in 1914 in Copenhagen by the International Polar Commission¹⁾. The only thing we could do was to fix days on which aerological ascents should preferentially be performed.

Then came the cessation of hostilities and with that the possibility of co-operation. The Norwegian Geophysical Commission therefore asked the Norwegian Government to invite the countries around the Arctic Ocean to erect geophysical stations in their Arctic regions. The Norwegian Government was willing to do this. As accompanying paper to the request there was a working programme for the stations.²⁾

The programme is as much as possible in accordance with that which was prepared by the Commission in Copenhagen in 1914¹⁾. However we found it desirable to extend it by including magnetic observations and photography of northern lights. The reason for this is not only that we wish to make the most of the stations which are to be erected, but chiefly that it is of great importance to get a base for the study of the connection between the northern lights and magnetic disturbances and the atmospheric conditions. They all depend on the solar radiation and the connection can most easily be seen in the Arctic regions.

We know that the solar radiation varies. There are considerable periods, such as the sunspot period, which have long been known and studied, but there are also shorter variations, which we have not been able to study until the last few years. When the solar radiation increases, the earth gets more energy. A part of the increased energy is radiated back, but a part of it makes the atmospheric machinery go faster. When the radiation is great the air movements are more intense than when it is small. It is the same as we see with other machineries; if we give them more energy they will go faster.

¹⁾ Procès verbaux des séances de la Commission Internationale Polaire d'Aérostation Scientifique. Réunion de Copenhague 28 février — 1. mars 1914. St. Pétersbourg 1914.

²⁾ Geophysical Investigations in the Arctic Regions in Co-operation with Roald Amundsen's Polar Expedition. This publication p. 5.

Nansen and Helland-Hansen¹⁾ have shown in a newly published work that this suggestion is correct. They have for instance found that the difference in pressure between low in Iceland and high in the Azores increases with the radiation. As to the temperature it will increase on the southern side of the mean track of the cyclones, because we there get more intense southern winds, while it will decrease on the northern side because of the intenser northern winds.

Further O. Krogness²⁾ has found a correlation between the magnetic disturbances and the varions meteorological conditions, espesially in the North of Norway. Finally may be mentioned, that it is commonly acknowledged that magnetic storms and the northern lights depend upon the solar activity.

For the reasons mentioned above it seems very probable that there exists a correlation between all the geophysical phenomena depending on solar radiation. This correlation can most easily be studied by means of a network of stations in the Polar Regions.

In the northern Atlantic, storms are very frequent and intense. Cyclones very often arise and traverse these Arctic regions. The magnetic storms are of course very much more intense in the Arctic regions than in more southern latitudes, and as to the northern lights they are rare outside the Arctic regions.

We see that all the geophysical phenomena mentioned are more intense in the Polar regions than outside them. The conditions for a study of a connection between them and the solar radiation are therefore most favourable in the Arctic regions.

Besides it is of course favourable to each science to get observations from a network of polar stations.

It will not be neccessary to discuss the importance of the meteorological and aero-logical observations as this is generally acknowledged and was dealt with by the International Commission at the meeting in Copenhagen. I will only mention that it will probably give results regarding the formation of cyclones (especially important for this study is a station on Jan Mayen) and regarding the general movements of the centres of action in the atmosphere.

As to the magnetic observations I refer to a paper by O. Krogness³⁾. Professor Størmer has in two papers given his opinion about the importance of photographing northern lights and the practical method of doing so⁴⁾.

For all the geophysical phenomena it is very important to have as close a network of stations as possible for drawing synoptical charts. It is therefore necessary to have rather many stations. On the chart (see fig.) I have marked down the European stations which we hope to get. As to the prospect of getting these stations, the following might be mentioned.

The Norwegian Government has now granted funds for erecting a geophysical station in Spitsbergen and extending the working programme of the observatories in Bergen

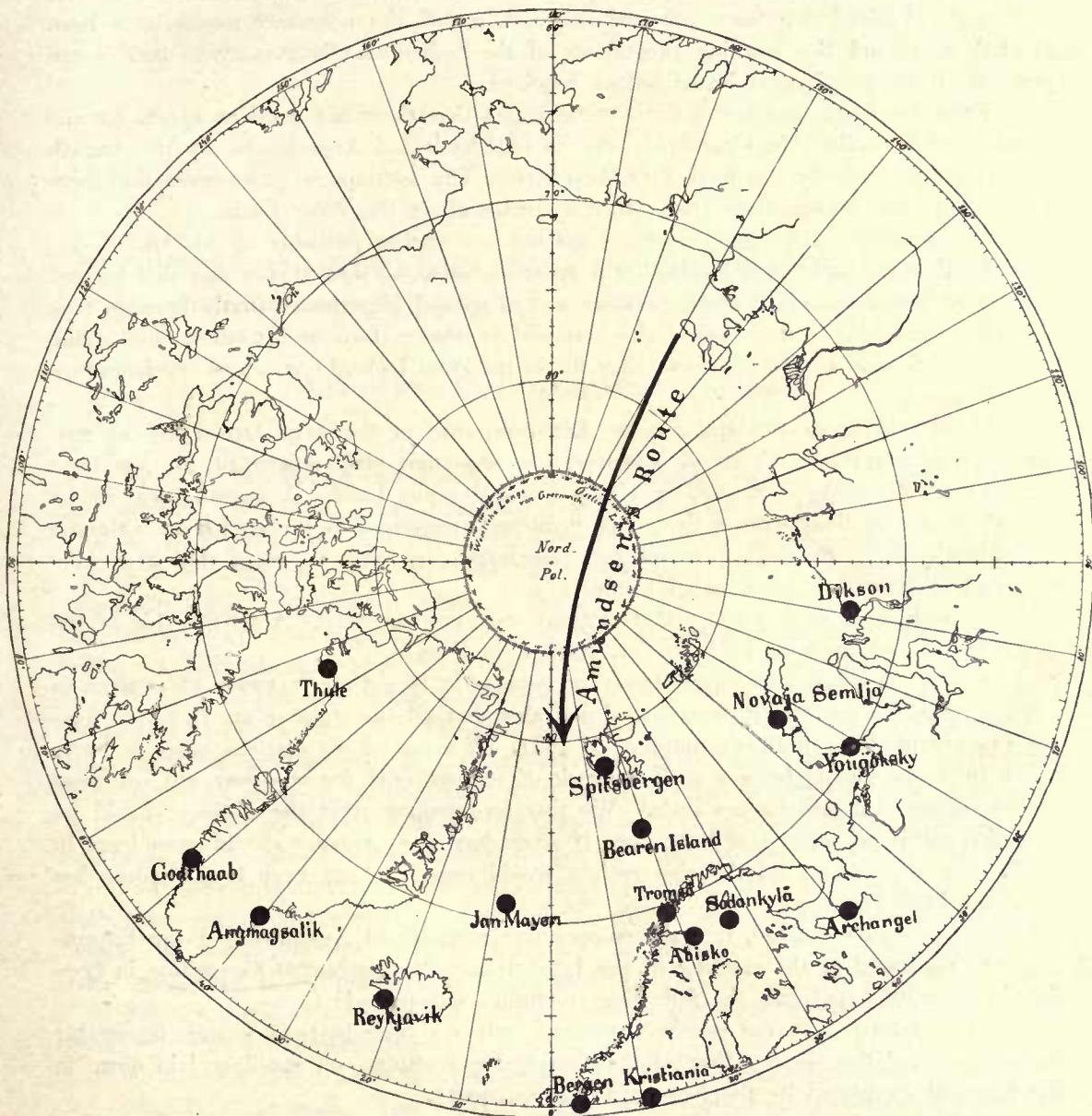
¹⁾ B. Helland Hansen and Fridtjof Nansen: Temperaturschwankungen des Nord-Atlantischen Ozeans. *Videnskabsselskabets Skrifter I Math. Naturv. Kl.* 1916, No. 9. Kristiania 1919.

²⁾ O. Krogness: De magnetiske stormes betydning i meteorologien. *Naturen* 1917.

³⁾ O. Krogness: The Importance of obtaining Magnetic Registrations from a comparatively close Net of Stations in the Polar Regions. This publication p. 8.

⁴⁾ C. Størmer: The Importance of taking Aurora Photographs from a Network of Stations around the Polar Basin in Collaboration with Roald Amundsen's Expedition. This publication p. 25.

Extract from a Report on Northern Lights Expedition to Bossekop — Store Korsnes in the Spring of 1913. This publication p. 20.



and Aas (near Kristiania) and the Geophysical Institute in Tromsø. We have not succeeded in erecting the station at Spitsbergen this summer because it was impossible to obtain the instruments in time, but it will be established as early as possible in the spring of 1920. Further it is probable that the Norwegian meteorological station on Bear Island will be able to make ascents with pilot balloons.

From the Central Hydrometeorological Station in Archangel we have received a telegram stating that there is an English pilot-balloon station at Murmansk, that ascents with pilot-balloons are now made at Dikson, and that geophysical stations will be erected at Archangel and Yougoksky. These stations will perform ascents with pilot-balloons. Further, we hope that the stations in Yougoksky and Dikson will per-

form magnetic observations and will photograph northern lights. The activity of these stations will however very much depend upon the future political situation in North-Russia.

From Finland we have received information that the necessary means have been granted to extend the working programme of the Sodankylä-Observatory so that it can perform all the geophysical investigations required.

From Denmark director Ryder communicates that there are good prospects for the erection of 3 stations in Greenland, viz. in Godthaab and Angmagsalik by the Danish State, and in Thule by the Kap York Committee. The assumption is, however, that there will be sufficient co-operation from other countries about the Polar Basin.

In Sweden we have good hopes of getting one station, probably at Abisko.

Further we hope, that England will erect a station on Jan Mayen and that Iceland will erect one station¹⁾. These stations are of special importance, firstly because they are the connecting link between the stations on the eastern and western side of the North-Atlantic and secondly because they lie in the great Iceland low, where cyclones are very frequent.

If we get these two stations, the European side of the Artic Ocean will be well furnished with stations. There is, however, one important place where so far we have no prospect of getting a station, namely in Franz Josephs Land. A station here will be a good connecting link between the above mentioned stations and the station on »Maud«, Amundsen's ship. Further, it would be exceedingly important to get a station on the eastcoast of Greenland at a high latitude.

It would also be important, that stations were erected on the American side of the Polar Basin, and we hope to get a few stations in Canada²⁾.

As the circumstances have made it impossible to get any network of stations in 1919, it must be considered exceedingly desirable that all the stations are in action from the summer of 1920 until the autumn of 1921. If some of the stations cease as early as in 1921, we should have a good network of stations only for one year and for most of the studies that will be too little. We therefore propose that the stations should be in action until the autumn of 1922 even if Amundsen unexpectedly should come back in 1921. On the other hand the observations would cease in 1922 even if Amundsen has not come back by then.

Finally may be stated, that the co-operation with Roald Amundsen's Polar Expedition was discussed at the meeting of the International Meteorological Committee in London in July 1919 and that the following resolution was passed:

»It is agreed that the members present will do their best to secure favourable consideration of the co-operation of their respective Institutes on the lines laid down in the proposal circulated by the Norwegian Government.«

At the great meteorological meeting in Paris in October 1919 there was established an International Polar Commission to lead the projected co-operation with Roald Amundsen's expedition. At the same meeting the days when Amundsen makes his aerological ascents (see table on page 5 of this publication) were fixed as days for the international aerological ascents all over the world.

¹⁾ From Iceland we have received information regarding the erection of a station at Reykjavik.

²⁾ In Canada the following stations will co-operate: Ft. Good Hope, Ft. Simpson, Dawson, Mc. Pherson, Herschell Island, and Bernard Harbour.

GEOPHYSICAL INVESTIGATIONS IN THE ARCTIC REGIONS IN CO-OPERATION WITH ROALD AMUNDSEN'S EXPEDITION.

BY
THE NORWEGIAN GEOPHYSICAL COMMISSION.

As Roald Amundsen had decided to start his Arctic voyage in the year 1914, the International Aerological Polar Commission held a meeting in Copenhagen, on February 28th — March 1st 1914, at which was planned an international co-operation with the expedition.¹⁾ They decided to promote the erection of a network of aerological stations round about the Arctic Ocean, where as far as possible, meteorological and aerological observations should be made as long as the expedition lasted. In the meantime the war broke out, international co-operation was impossible, and the expedition was postponed.

In spite of the war, Roald Amundsen managed to start his expedition in June 1918. He took with him a large and first-class meteorological and oceanographical outfit, and instruments for measurements of the terrestrial magnetism and investigations of the northern lights. In addition, he succeeded in engaging the meteorologist Dr. H. U. Sverdrup as leader of the scientific work of the expedition. The latter has therefore the best conditions to be able to make valuable geophysical investigations in the Arctic regions. However, these investigations have much less value when they are performed isolated than when geophysical observations are also made at stations round about the Arctic Ocean. It would therefore be most valuable if as many geophysical stations as possible could be erected to co-operate with the expedition.

For the work of these stations, there has been made out the following plan in close agreement with the determinations in Copenhagen:

1. As long as Roald Amundsen's expedition lasts aerological observations are as far as possible to be made. This will be of greatest importance in the principal year 1920, when Amundsen will be nearest to the North Pole. Later on there shall in any case, even at stations of limited material, be taken observations on the days given in the following table.

TABLE OF FIXED DAYS.

	Jan.	Febr.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1919	2	5—7	6	3	8	4—6	3	4—9	4	8—10	6	4
1920	7—9	5	4	8	5—7	10	5—10	5	8—10	7	4	2
1921	6	3	3	6—8	12	6—11	7	3—5	8	6	3	7—9
1922	5	2	8—10	6	8—13	8	5—7	3	7	5	1—3	7
1923	4	7—9	8	2—7	3	6—8	5	2	6	3—5	8	6
1924	2—4	7	3—8	3	7—9	5	3	7	3—5	2	6	4

¹⁾ Procès-verbaux des séances de la Commission Internationale Polaire d'aérostation scientifique, Réunion de Copenhague 28 février — mars 1914. St. Pétersbourg 1914.

By arrangement with Dr. Sverdrup, the expedition will on these days make ascents with registering balloons, kites, captive balloons or pilot balloons.

2. The following programme for observations must be considered necessary:
 - a. Meteorological observations such as are performed at a first order station.
 - b. Pilot balloon ascents, which at least in the year 1920 are to be performed daily.
 - c. Observations made as frequently as possible on the direction and velocity of the motion of clouds.
 - d. Kite ascents, ascents of captive balloons, and as far as possible of registering balloons, at the stations intended for the purpose.
3. The stations are to perform observations at three fixed hours daily (local time). On the fixed days given in the above Table, there shall be performed at 7 a. m. (Greenwich Time) direct observations of all meteorological elements, and at the same time aerological ascents are to take place.
4. As the expedition is taking with it registering apparatus for terrestrial magnetism, it will be of great importance that the stations are also as far as possible equipped with such apparatus.
5. The stations are if possible to be equipped with apparatus for the photography of the northern lights.¹⁾ It is especially requisite to secure photographs on the above mentioned fixed days. The best thing would be to perform photography of the northern lights simultaneously at two stations connected by telephone, for the determination of the height and position of the northern lights, the stations being at a distance of about 25 km. from each other. If no basis can be obtained, the northern lights should be photographed from one station. It may then be limited by only photographing coronas and quiet, regular arcs and bands for the determination of their accurate position among the stars. It is especially of importance to obtain photographs of the highest point of the arc and the terminal points on the horizon in speedy succession, in order to get variations with the time.

The usual observations of the northern lights are also required, particularly the hour for the appearance of special forms, e. g. coruscation, corona and drapery formations. These observations should also be made at the stations which are not equipped with apparatus for the photography of northern lights.

Further the following may be emphasized:

6. It is essential that possible Arctic expeditions e. g. aeroplane expeditions, should be equipped with instruments so that they can in a scientific respect co-operate with Roald Amundsen's Arctic expedition. It is particularly of importance to perform aerological observations on the fixed days given in the above Table.
7. The observations should be published as soon as possible. A collective scientific treatment of the material will be carried out by Dr. Sverdrup.
8. Owing to the limited time it is to be foreseen that it may be impossible to establish all the stations in the year 1919. Stations which are established in the summer of 1920, will also be of exceedingly great importance.

As the matter is of great importance it is hoped that the Norwegian Government will grant the necessary funds to establish kite and registering balloon stations at Spitsbergen, Tromsø, Kristiania, and Bergen. In the north of Russia it is likely that there

¹⁾ Concerning the photographing of northern lights refer to the following papers by C. Størmer:

Sur les trajectoires des corpuscules électrisés dans l'espace. 21 *Archives des sciences physiques et naturelles*, Genève 1911.

Terrestrial magnetism 1913, 1915, and 1916.

Astrophysical Journal Nov., 1913, and April, 1916.

Comptes rendues. Paris 16. June, 1913, and 13. March, 1916.

Bulletin de la Soc. astr. de France, Nov. 1913.

will be established 2 or 4 pilot balloon stations by the «Central Hydrometeorological Station» at Archangel. It is hoped that the countries to which the Norwegian Government will send a request to take part in the scheme, will do this as far as is in their power. We have here an exceedingly good opportunity of extending our knowledge and understanding of the geophysical conditions of the Arctic regions.

Communications concerning the erection of stations and their working programme should be sent to the Norwegian Meteorological Institute, Kristiania.

Kristiania, February 1919.

THE IMPORTANCE OF OBTAINING MAGNETIC REGISTRATIONS FROM A COMPARATIVELY CLOSE NET OF STATIONS IN THE PÖLAR REGIONS.

BY
O. KROGNESS

I.

As regards magnetic storms, the Polar Regions are by far the most interesting part of the earth, but the study of magnetic variations has until now mainly been conducted in the lower latitudes where practically all the fifty magnetic observatories of the world are situated.

No permanent observatory had been erected in the vicinity of the auroral zones until the Norwegian Government, in accordance with a proposal by the late Professor Kr. Birkeland, founded a small observatory of this kind at Mt. Haldde in the most northerly district of Norway.

On the other hand, attempts have sometimes been made by different expeditions to study these magnetic conditions in the Polar Regions at a special station e. g. Scott's expedition to the Antarctic, Amundsen's expedition to the magnetic North pole, the German Drygalski expedition to the Antarctic Regions, and the German station at Cross Bay in Spitsbergen during the years just preceding the outbreak of the war.

The material which special stations such as these will give is, it is true, in many respects most interesting, but for the intimate study of the magnetic storms they only give an exceedingly scanty material.

Only twice have there been made greater efforts to obtain a better insight into the true nature of magnetic storms, viz. during the international Polar expeditions of 1882—83, where a series of in all 11 polar stations were scattered round the northern auroral belt and by the Norwegian expedition of Birkeland in the winter 1902—03, during which 4 polar stations were simultaneously in operation.

In the expeditions of 1882—83 the magnetic elements were read once every hour, except on two days of each month when readings were made every 5 minutes.

For an intimate study of magnetic storms it is only the observations on these special days that are of importance. The other hourly readings may give some enlightenment as to the field of force, but no detailed study of the individual perturbations can be based upon these observations.

There is thus available a rather limited material from that year. The most characteristic storms that occurred in the interval cannot be selected and studied, and only

those few cases that, more or less by chance, occurred on the previously determined term-days are available for study.

In spite of this the material from that year, however, really does contain a comparatively large number of storms, and the stations have a very favourable position round the Auroral Zone, so that in fact the material is a most valuable one for such studies.

In two respects, however, the material is rather incomplete, viz. there are no measurements from the Polar Basin, and the observations from the medium and lower latitudes are comparatively very few.

From the year 1902—03 there exists from lower latitudes a quite close net of magnetic observations, but on the contrary the observations from the Polar Region are very incomplete. In those latitudes, situated about 10 to 15° to the South of the Auroral Zone, in which region the strength of the magnetic force during Polar storms drops from its maximum value down to about 1/20th of the same, there were no observations at all.

Both of the materials that exist are thus somewhat incomplete, but on the other hand they form a quite good complement to each other.

By studying the fields of force of the magnetic disturbances, side by side with the above materials, it was possible for Birkeland to obtain a quite satisfactory comprehension of these mighty and most interesting phenomena, of which practically nothing was known formerly.

He succeeded in finding the main features of the typical field of force of magnetic storms, and was further able to demonstrate, that the fields of force found naturally might be explained as the magnetic effect of those systems of electric rays which according to his theory were emitted from the sun and »drawn in« towards the earth in the regions of the Auroral Zones. The magnetic effect observed was, he thought, partly a direct magnetic effect of the primary outer electric ray-systems, partly the magnetic effect of electric current induced in the earth by the variations in the extra-terrestrial system. Similar currents he also thought might possibly exist in the upper strata of the atmosphere, where perhaps the electric conductivity was of quite another order of magnitude than in the vicinity of the earth¹⁾. The effect of the earth currents could be directly demonstrated by the aid of registrations. They prove to have a comparatively great effect, especially in lower latitudes at some distance from the »storm-centres«, but in the vicinity of the latter, the direct magnetic effect of the outer systems seemed to be the predominating one.

As to the possible effect of intra-atmospherical systems nothing could be decided on account of the complete lack of observed facts to go upon. I think he scarcely believed that intra-atmospheric electric current systems were in any case of essential importance. How far this is true is a question still open for investigation and to which I may recur later on.

The current systems which Birkeland found in the Polar storms were all situated in the vicinity of the Auroral Zones, but there were some facts that indicated the possible existence at »zones of precipitation« for the rays that sometimes, perhaps also generally, stretch across the Polar Basin, or perhaps there were in those districts more or less independent or isolated systems of precipitation²⁾.

The existence of these could, however, not be stated with certainty.

As I shall mention later on, it seems possible, by magnetic observation at a single station, in connection with simultaneous observations of the auroral development, to decide the question of the existence or non-existence of systems of precipitations such as the above. And as in my opinion it is of very great interest to decide whether such systems do exist in those districts through which the »Maud« Expedition will now pass, I

¹⁾ Kr. Birkeland: The Norwegian Aurora Polaris Expedition 1902—03, cf. f. i. p. 443.

²⁾ L. e. cf. f. i. pp. 352—354 and p. 375,

thought it advisable to make an attempt in this direction. The problem of making magnetic registrations on board a ship drifting in the ice of the Polar Ocean is of course not a very easy one. Some people, accustomed to the ordinary magnetic registrations in lower latitudes, where a very great precision in the measurements is afforded, might perhaps find it impossible.

On the other hand, we should remember that in the first place the Polar ice very often forms a very solid fundament, so solid, that very fine pendulum observations can be made with comparative ease, secondly the diurnal variation in the magnetism will at any rate during the winter be very small, so that when a magnetic storm-centre occurs in the vicinity of the station during that time, the whole deflection would practically be due to the magnetic storm in question. As the ordinary and most typical perturbations of moderate magnitude do not last more than a few hours, it may very well be possible to obtain registrations of such magnetic storms with a set on board ship when the ice screwings are not too great.

In my belief that such observations were within the range of possibility, I was confirmed by a conference with Mr. Scott-Hansen, who carried out the pendulum observation on the »Fram« on the Nansen North-Pole Expedition.

When the new North-Pole Expedition of Amundsen was planned I therefore tried if it were possible to build magnetic registering apparatus, that were so simple and easy to mount that they could be useful for such registration.

It would be a very great advantage if it were possible to use mechanical registrations instead of the ordinary photographic ones, and the experiments which I undertook on Mt. Haldde shew, that this in fact was possible for the two horizontal components. For the expedition we built two such mechanically registering magnetometers for the horizontal elements, and one photographically registering for the vertical elements. Further the expedition was equipped with a small photographically registering clinometer from Toepfer.

Although there will of course be many practical difficulties to overcome on board ship, — or on the ice — in connection with such registrations, the possibility is present that the expedition will succeed in obtaining a series of magnetic registrations from these exceedingly interesting parts of the earth. Dr. H. U. Sverdrup, with whom we conferred about these observations, was very interested in the matter, and hoped it would be possible for him to obtain usable registrations on board under favourable conditions.

The question then naturally arises if it is possible to undertake similar registrations on the planned Polar stations. According to the above statements, such registrations would be exceedingly valuable in themselves, and still more interest may be attached to them if we succeed in getting simultaneous registrations from the »Maud« Expedition.

The first point that must be considered is the question of an instrumental equipment suitable for use by such expeditions. The difficulties that arise are so considerable, that every possible facilitation must be adopted.

In the following I will try to describe some very simple registering arrangements which I think will be well fitted for expeditional use in the Polar regions, and further give a short description of those apparatus that were constructed for the »Maud« expedition.

As this question will perhaps also be of interest to those not familiar with the methods in general use, I will give the description somewhat in detail.

II.

ON SOME SIMPLE ARRANGEMENTS FOR MAGNETIC REGISTRATIONS.

The ordinary way in which magnetic registrations of the horizontal E. W. components are undertaken is the following: A magnet is hung up on a thin thread and left

to itself. The axis of this magnet will then direct itself magnetically N. S. When a new magnetic field superpose the ordinary permanent field of the earth magnet, the E. W. component of this new field will deflect this magnet from the magnetic meridian. For the same disturbing force-component this deviation will be greater when the horizontal intensity of the earth magnetism diminishes. If the earth-magnetic field in the place where the magnet hangs is superposed by fields of permanent magnets acting in the opposite direction, the real total field intensity in this place may be reduced as much as one may desire. Accordingly, the deviations will be enlarged in the same degree.

To the magnet is fixed one or more mirrors, and by the aid of these and a system of lenses, the light from a slit is projected in the form of a luminous spot upon a cylinder covered with photographic paper.

When the magnet moves, this projected spot of light will move along the paper of the cylinder, and at every moment mark out the position of the magnet. In those districts (in medium latitudes), where the horizontal intensity of the earth magnetism is of the order 0.2 units C. G. S. — or $20\ 000\ \gamma$ — a perturbing force of $200\ \gamma$ in the direction E. W. magnetically on a free magnet will produce a deflection α defined by

$$\tan \alpha = \frac{200}{20\ 000} = \frac{1}{100} \text{ or } \alpha = \text{about } \frac{1}{2}^\circ$$

On the photographic paper this will produce a deflection x defined by

$$x = 2 \cdot A \tan \alpha,$$

where A is the distance between the magnet and the cylinder. When A is 1 m., x will be about 2 cm., or 1 mm. deflection will correspond to $10\ \gamma$. Ordinarily the distance A , and correspondingly the sensitiveness of the arrangement, is chosen somewhat greater.

In the Polar regions, however, the disturbing forces will be considerably greater. Disturbing forces of the order $1000\ \gamma$ will not be very rare, and on the other hand the horizontal intensity of the earth magnetism will be considerably smaller.

In those districts where $A = 0.1$ C. G. S. ($10\ 000\ \gamma$) the deflection corresponding to a distance $A = 35$ cm. and a disturbing force of $1000\ \gamma$ will be

$$x = 2 \cdot \frac{1\ 000}{10\ 000} \cdot 35 \text{ cm.} = 7 \text{ cm.}$$

The sensitiveness by such an arrangement will be about $14\ \gamma$ pr. mm. This sensitiveness will be quite reasonable in those districts and it is thus evident that suitable apparatus for these regions may be constructed so small in size, that the whole arrangement, magnet and cylinder, may be built in a small case, and thus the registrations may be undertaken in a lighted room.

Such apparatus were formerly constructed by Toepfer, but these have not been available during the war.

If magnetic registrations are to be undertaken by the Polar expeditions planned, it is of great importance that the apparatus which will come into use, should be as simple, small in size and handy as possible. Every refinement which is not necessary and which may cause trouble to an observer who has no great experience in these observations, must be omitted.

According to these principles, we have built some very simple types of magnetic registering apparatus, one of which is demonstrated in Fig. 1 by some photographs.

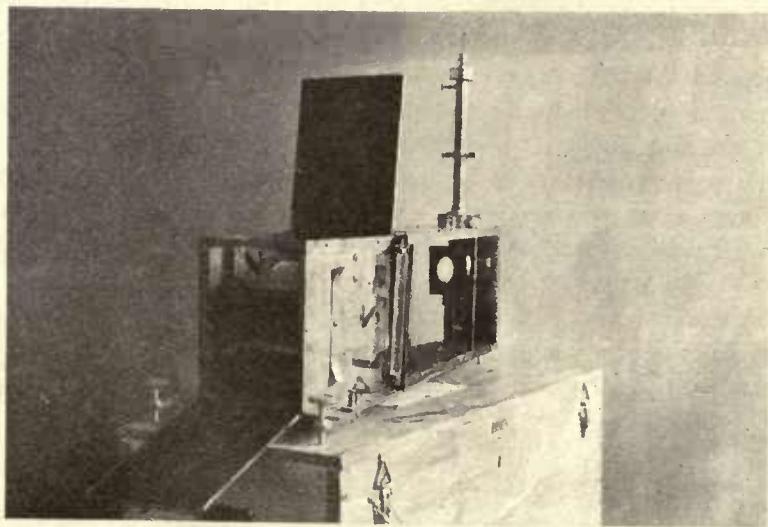
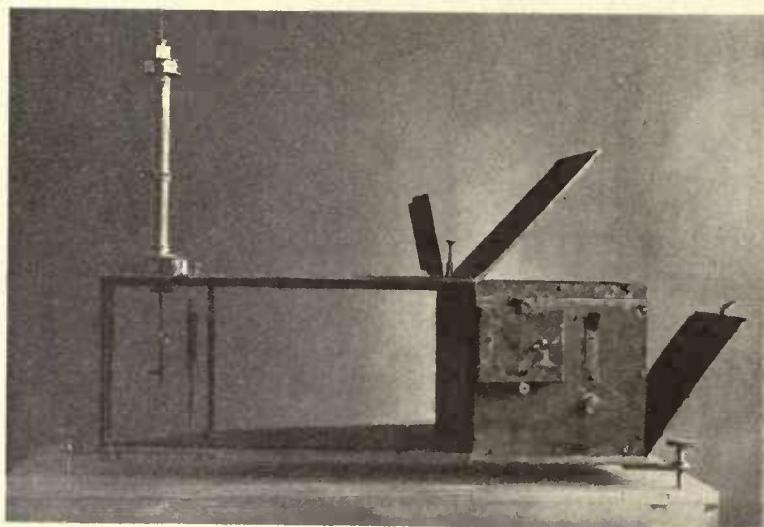
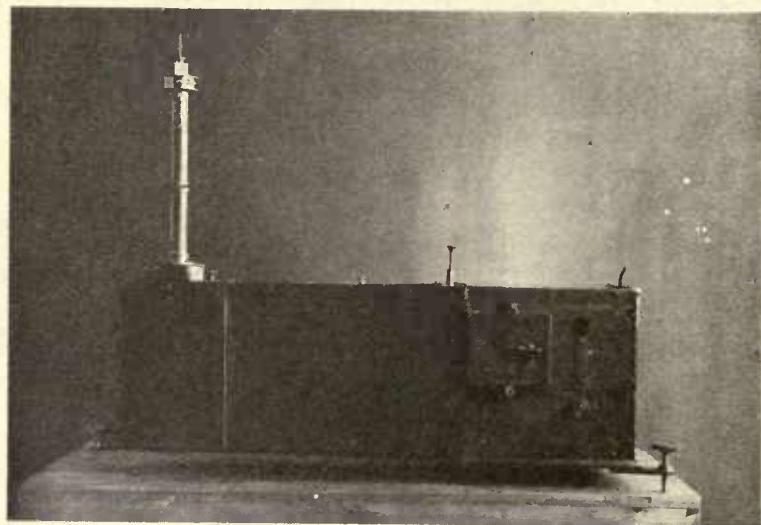


Fig. 1.

This instrument does not need a dark room, the registrations may be undertaken in an ordinary lighted room.

If it is difficult to reserve a special room for these registrations, even a room that is set aside for other work may be used, if some care be taken that not too much work is done near the instruments. In such a case a damping arrangement must be used; the simplest arrangement will be to put an oil or petroleum damper beneath the magnet.

In the ordinary registrations at the observatories a copper-damper placed in the immediate vicinity of the magnet is employed. When the base of the instrument, however, is not very steady, the magnet will by such an arrangement very easily stick to the damping box, and in that way the registrations will be destroyed. In oil-damping a rather large damper-cup may be chosen so that no accident is to be feared.

As slit there is chosen a capillary glass-tube, from the inner part of which the light from the lamp will be totally reflected. In this way it will act as a very sharply lighting slit. For the position of the lamp by this arrangement there will be greater room for freedom than would otherwise be the case.

Those who have tried to put up hastily a set of magnetic registering instruments, will have experienced many practical difficulties in the arrangement of the mirrors when there was a very limited space round the magnet. This space is in general so small, that it is impossible to fix the magnet-suspension with the fingers and adjust the mirrors on the place. In the above instrument this is very easy to do. The suspension is intentionally made large, and the open space around the magnet is very great, so that there is no difficulty in making all the adjustments by the magnet when this is in place. To the magnet are fixed in all 4 mirrors that form small angles with each other, an arrangement which is intended still more to facilitate the adjustment.

To the brass tube on the roof of the case is fixed a slide with two magnets which may be moved up and down. By the aid of this the strength of the magnetic field in the place of the registering magnet may be diminished or increased at pleasure. In this way it is very easy to obtain just the sensitiveness which is desired.

The sensitiveness of the instruments is ordinarily obtained by measuring the real horizontal intensity of the earth magnetism on the place. This measurement demands a fine and rather expensive instrumental arrangement, which perhaps is hardly to be had in these days. The measurement of the absolute value of the horizontal intensity is also an operation that demands some experience. In order to make such a measurement superfluous, an electric arrangement is fixed to the apparatus beneath the bottom of the case. Two copper threads close together lead to a coil below the magnet. When an electric current is sent through this coil, the magnet will be deflected, and the deflection is directly proportional to the intensity of the current. When the instrument therefore is adjusted beforehand and the position of the magnet is fixed, the sensitiveness can at once, without any difficulty, be determined by the aid of an ammeter, — or milliammeter of sufficient accuracy. Such a determination may be obtained each day, if desirable twice the day, — or one may make such an arrangement that the determinations are made automatically every hour, and the break in the curves, which in this way is effected, may with advantage serve as hour-marks.

The suspension thread which I have used is a very thin brass thread. Ordinarily the suspension thread is made of quartz, but if this is sufficiently thin, it is much more difficult to handle than a brass thread, and the former has in reality no essential advantage over the latter in this case.

The N-S-component of the magnetic disturbing force is generally registered in quite a similar way. The magnet is now suspended on a vertical thread as before; it is, how-

ever, now forced to take a direction perpendicular to the magnetic meridian; either by twisting the suspension thread or by deflection by fixed permanent magnets. The component of the magnetic force in the place which is able to deflect a magnet suspended in this way is that directed in N. S. The deviations, which we obtain by this arrangement will therefore be proportional to the variations in the horizontal intensity.

For the registrations, the same apparatus may be used; the magnets fixed to the slide on the upper brass-tube may at the same time be used as deflecting magnets and serve to reduce the strength of the earth's magnetic field, so that any desired sensitivity may be obtained. It may be remarked that the variations in temperature by this registrations will have a greater influence on the registrations. Care must therefore here be taken to avoid too great diurnal changes in the temperature. For the magnetic storms in the Polar regions, slow temperature changes will hardly be of any importance for the determination of the diurnal variation. It is, however, of importance to have the diurnal temperature-variations reduced as much as possible. I do not think any special temperature-compensation will be needed here.

The sensitiveness of the instruments may be determined in the same simple way as formerly described, by conducting an electric current through the coil beneath the magnet. When we direct the axis of this coil under an angle of 45° with length direction of the apparatus, the magnetic effect of this current on a magnet directed parallel to, and perpendicular to, this direction, will be of equal magnitude (the deviations supposed not to be too great).

The most convenient mode of arranging these registrations will therefore be to direct the »axis« of the whole apparatus magnetically S.-N. (or E.-W.), which is easily done by the aid of a compass, then to direct the movable magnet in the one apparatus exactly parallel to the length direction of the case, and that of the other perpendicular to the same direction. Then when the coils are made exactly similar and the dimensions of the two cases are the same, one may lead the same electric current through the coils put in series, and then determine the strength of the current by the aid of an ampèremeter. When the coil-axis forms the angle 45° with the case-direction, the deflections produced in the two apparatus will then correspond to the same disturbing force, provided that the instruments are placed at so great a distance from one another that the effect of the current circuit of the one apparatus is imperceptible in the situation of the other. If this is not the case, a special determination must be made for each instrument separately.

To obtain registrations of the variation of the vertical magnetic component we must have a magnet which has a horizontal position, and which moves on a *horizontal* axis. This is ordinarily obtained in a Lloyds Balance by placing the magnet on a knife, — or on two needles placed on a plate of agate (with a slight hyperbolic curvature).

The magnet is forced to take this position by the aid of special weights or permanent magnets counteracting the vertical earth-field. To the magnet is fixed a mirror, and the deflections of this magnet may be registered photographically in a similar way to that of the horizontal elements.

The sensitiveness of this magnet is dependent on the distance between the point of density and the axis of revolution, and may be regulated by small weights attached to the magnet.

Another way of procedure, which as far as I know has only very seldom been employed, e. g. by Angenheister and Tanakadate, is to fix the magnet to a horizontally suspended fine thread instead of placing it on a knife. This mode of procedure is in my opinion considerably more advantageous in many respects. By tightening of the thread we have a very easy and convenient means of adjusting the magnet without touching it

with our fingers. We have made some experiments with suspension of that kind and found it very advantageous.

With such an arrangement special care must be taken, that the tightening of the suspension thread must be constant.

The registering arrangement may be built in a way similar to that of the apparatus previously described, but the suspension must be arranged somewhat differently.

We have not built any complete apparatus of this kind, but in Fig. 2 there is shown a very simple apparatus that without any difficulty may be built in the larger registering case.

On the top of the small case there is placed a mirror, by the aid of which the light from the slit is bent vertically downwards, where it passes through a lens of con-

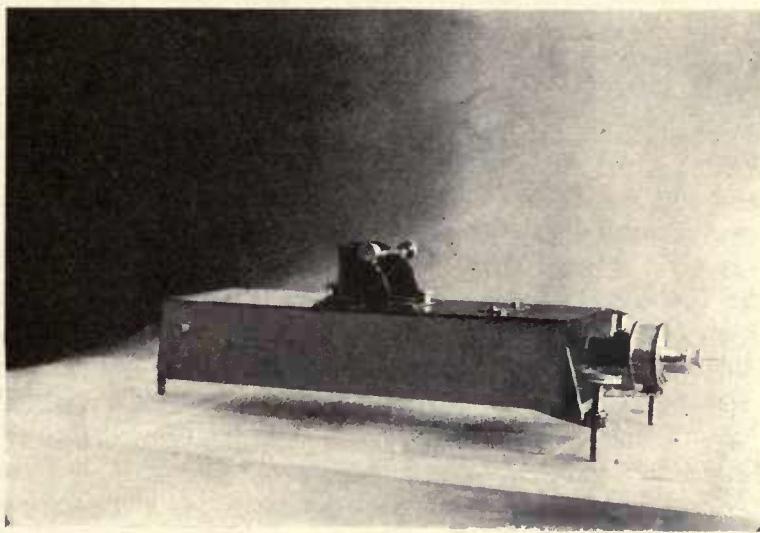


Fig. 2.

venient focal length, and afterwards, as parallel rays, falls upon the mirror fixed to the horizontally suspended magnet in the interior of the case. From this mirror the light is reflected upwards, again passes the lens and the upper mirror, and forms a picture of the slit in the focus-plane of the lens, where the cylinder with the photographic paper is placed. Here the picture of the slit will by a cylinder lens be deformed into a luminous spot in the same manner as in the horizontally registering instruments.

The torsion-head of the suspension must now be placed on a small horizontal tube placed on the large case on the opposite side of the registering arrangements.

The constant tightening of the thread is, according to a proposal of my colleague Devik, secured by a simple special arrangement of a constantly loaded scalebeam.

As the temperature co-efficient of such an apparatus will ordinarily be comparatively very great, some arrangement ought to be made in order to counteract this temperature influence. This may here be obtained in the same way as is ordinarily done by placing a permanent magnet above (or below) the movable magnet. Such an arrangement may easily be made by fixing a magnet in a brass tube on the roof of the large case.

The determination of sensitiveness is also here most conveniently made by an electric circuit placed in a convenient position in the apparatus.

Especially by the arrangement of the thread-suspension mentioned, I do not think it will be very difficult, even for observers not acquainted with the matter, to undertake these measurements.

It seems to me that by these apparatus all those practical difficulties which are met with in the general magnetic registrations have been set aside, and nothing is done that will diminish the accuracy of the registrations.

It is my conviction, that instruments such as these will make it possible to obtain in an easy way valuable material for magnetic registrations from the Polar stations.

It is our intention to try to place instruments of this or a similar kind on Spitsbergen, Bear Island, and in Norway, to try to get registrations from Haldde, Tromsø, Dovre and Kristiania, perhaps also from Bodø, Trondhjem and Bergen.

This net of stations we hope will give a very complete demonstration of how the magnetic field in the disturbed regions varies when we move from the auroral zone southwards, a most important district from which observations of this kind have as yet never been obtained.

III. EARTH-CURRENT REGISTRATIONS.

As I mentioned above, a considerable part of the deviation measured under magnetic disturbances is due to earth-currents, the smaller deviations of short duration are for the greater part due to earth-currents. It is therefore very desirable, as a complement to the magnetic registrations, to get registrations of earth-currents. Such registrations may also very easily be arranged on a single telephone line. For the height measurements of the aurora it is necessary if not a wireless telephone is used to have a telephonic connection between two stations, and to this a registering milliamperemeter may be attached in a simple way. If we have a single telephone line connected with earth at both ends, the milliamperemeter may be put directly in series with the line. This will not essentially disturb the distinctness of speech, and the telephone currents will not disturb the registrations. In order to get continuous sensitiveness it is only necessary to make an arrangement which will ensure that the resistance in the circuit will be the same when the telephone is used as when it is out of use.

Riehard Frères has constructed an apparatus very handy for this purpose, which makes the registrations mechanically in ink on paper.

Although it may not be considered necessary to combine the magnetic registrations with such earth-current registrations, it is, as already said, desirable, and moreover it is useful for observations of the aurora as the apparatus that may be placed in the public room will show when the auroral displays begin. It may also be convenient — as we have done — to attach an electric contact to the milliamperemeter, so that an electric bell will ring each time when the deflections reach a certain strength. The apparatus may then serve as an »alarm bell« for the aurora.

IV. THE INSTRUMENTS ON BOARD THE »MAUD«.

As mentioned above, we have also sent some registering magnetic apparatus with the »Maud« Expedition. In the very exceptional conditions under which the registrations will have to be carried out, where the whole ship must very often be expected to undergo very strong variations in the azimuth, it was thought advisable to make such an arrangement, that the position of the needle could be observed, and an adjustment could be made taken as easily as possible. In view of these conditions we thought that the most convenient form of magnetic register would be an instrument which made the registrations not photographically but mechanically. The experiments which we undertook on the Haldde showed that it was possible to get quite satisfactory results in this way.

The deviations registered in this way will only be the half of those registered in the same way photographically. To secure convenient sensitiveness it is therefore here necessary to make a considerably greater reduction in the force of earth-magnetism than by the photographic registrations, if another kind of enlargement of the deviations is not used. It is, however, here necessary to enlargen the sensitiveness as much as possible, also of that reason that deflection must be obtained that are greater than the small azimuthal changes of the vessel itself which of course constantly will occur.

Experiments showed that it was not difficult by the aid of a system of permanent magnets to lower the intensity of the field so much, that we secured a sufficiently great sensitiveness was obtained.

The principles of construction were as follows. To the magnet was fixed a pin which was pointed over a cylinder covered with blue paper.

Between the pin and the cylinder there was stretched a fine thread. Then the pin, by an electro magnetic arrangement, was pressed down on the thread, say every 5 minutes. On the paper there was obtained a blue point which indicated the position of the magnet, and was made as small as possible. As the iron in this arrangement formed a closed circuit, the outer field would hardly be perceptible at some distance.

As further, the registering magnet is only free and takes its position when the electro-magnet is not magnetized, there will be no essentially disturbing effect caused by this arrangement.

A very large fluid-damper is necessary, as it will otherwise take a very long time for the magnet to come to rest.

The whole apparatus was intended to be hung up in Cardan suspension, and the arrangement of the cylinder was made for »endless roll«.

For the registering of the vertical intensity an instrument was built on a somewhat different principle to that usually adopted. A thread-suspension was used, and by the aid of a system of reflections the instrument was reduced to a very small size. The registrations were there made on photographic plates $4,5 \times 12$ cm.

It will, however, be of no special interest in connection with the present question to give a minute description of this apparatus.

V.

THE INTEREST WHICH IS ATTACHED TO MAGNETIC REGISTRATIONS IN THE POLAR REGIONS.

As mentioned above Birkeland made very intimate studies of the fields of force connected with the magnetic disturbances based on such materials as were available and fitted for these studies. As further mentioned these materials were in many respects incomplete, but on the other hand it was possible, by their aid to find the typical forms of these fields of force, and a series of general laws on which they were based.

Birkeland thought by these studies to find very good confirmation of the theory which he had formerly held, that the magnetic disturbances were directly caused by electric, or radioactive, rays that were emitted from the sun from special »active« regions.

Subsequently some doubt has been expressed as to whether the details of Birkeland's theory on this subject may hold good. Sir Arthur Schuster in particular has expressed the opinion that the original energy that is afforded when for instance a rather limited number of rays should pass from the sun to the earth, must be of such an enormous order of magnitude, that it can scarcely be conceived. On account of the mutual electrostatic repulsion of the corpuscles, he finds that such a bundle must very soon be scattered so much, that no so great effects as one observes during magnetic storms

will be possible. He thinks it possible that an ionising effect in the higher strata of the atmosphere may release intra-atmospherical currentsystems, that may give rise to magnetic effects such as those found during the disturbances.

However, so far as I know a more intimate proof of this supposition has not been forthcoming, and it seems to me that rather serious difficulties may arise when a theory such as this has to be elaborated in detail.

On the other hand Schuster, as he himself remarks, has not taken into account some moments which perhaps will play a not unimportant part, especially the fact that the magnetic field of the earth may transform a very scattered ray bundle in space into a very concentrated system in the auroral belts; further, as Birkeland also has remarked, Schuster only took into consideration the electrostatic repulsion of the corpuscles and not the electrodynamical attraction, which would counteract the first effect when the velocity of the rays is great.

Further, the possibility that the ray bundles may contain both negatively and positively charged particles has not been taken into consideration.

This is not the place to try to form a clear judgment as to how far the objections that may be raised against the different theories may be of decisive importance. What is here of interest is that no theory may be said to be fully stated in all details. The only way in which this may be done is to try to collect a material as complete as possible, both from higher and lower latitudes, and then to combine these with simultaneous and careful auroral observations.

It may also be considered interesting to combine this research with some observations of atmospheric electricity. On the »Maud« Expedition ordinary measurements of potential gradient and conductivity will be carried out, and it would of course be of interest to have similar observations undertaken at the Polar stations. An exceedingly interesting material might, however, be obtained if atmospheric electric researches of any kind could be carried out in connection with the ascent of captive balloons or of registering balloons. Just before the outbreak of the war most interesting results were obtained by such ascents. It was stated that from an altitude of not more than about 2000 m. and up to the greatest heights reached there existed quite abnormally intensive penetrating rays¹⁾. Researches into this very interesting phenomena in the Polar Regions would certainly be most valuable, in connection with both the aurorae-phenomena and the magnetic storms, — and perhaps also for meteorology; but it is doubtful whether a suitable registering arrangement have till yet been constructed. And it is, therefore, hardly to be hoped that researches such as these will be within the range of possibility on the Polar expeditions.

For the study of the aurora the magnetic registrations are of course of the greatest importance, as there exists an intimate connection between these. But how this connection is to be understood in detail is a problem, that is not yet sufficiently elucidated.

¹⁾ Cf. W. Kolhorster, Beitr. z. Phys. d. fr. Atm. Bd. 7, p. 87. Simpson, Nature, Vol. 99, p. 124.

EXTRACT FROM A REPORT ON THE NORTHERN LIGHTS EXPEDITION TO BOSSEKOP—STORE KORSNES IN THE SPRING OF 1913.

BY

CARL STØRMER.

§ 1. *Previous expeditions, having for their object the taking of photographs of the Northern Lights for the determination of their height and situation.*

The expedition of 1913 was a direct continuation of that which I undertook to Finmarken in 1910, and it is therefore necessary to say some few words regarding its results. A detailed account was printed in the publications of the Videnskabsselskabet for 1911.¹⁾ As is known, we were successful during this expedition in taking for the first time a number of photographs of the Aurora, the time of exposure being reduced to a few seconds. This result was partly due to the employment of an extremely luminous cinematograph lens *Ernemann Kinostigmat*, with a diaphragm of 25 mm and a focal length of 50 mm, and also partly to the use of extremely sensitive plates, Lumière étiquette violette. Several hundred successful photographs of the Aurora were taken. These single photographs gave a good impression of the many characteristic forms of the Northern Lights and were thus of considerable scientific interest. Of far greater importance, however, was the method of photographing and determining the height and situation of the Northern Lights which I employed for the first time during the expedition of 1910.

The method of procedure was to take simultaneous photographs of the Aurora with known stars as a background, from two stations connected with each other by telephone. From the time, and the parallax measured out on the plates, the height and situation of a number of points on the Northern Lights could be determined. We will call such »pairs« of pictures *photograms*. With a distance between the stations of $4\frac{1}{2}$ km., there were taken about 40 simultaneous photographs of the Northern Lights, and these gave about 140 determinations of height. Of these many were not certain, partly on account of the great height of the Aurora in relation to the selected base, and partly on account of its unfavourable situation in the heavens with relation to the position of the base line. In 1911, with a base of 27 kilometers (from Christiania to Aas) I succeeded in taking a number of photograms. My method was employed in the winter of 1912—

¹⁾ Bericht über eine Expedition nach Bossekop zwecks photographischer Aufnahmen und Höhenmessungen von Nordlichtern, loc. cit. Math. Naturv. klasse 1911. No. 17, with 57 figures and 88 plates.

See also: *Sur les trajectoires des corpuscules électriques dans l'espace sous l'action du magnétisme terrestre avec application aux aurores boréales. Second mémoire, Troisième partie, Archives des sciences physiques et naturelles, Genève 1912.*

1913 by Dr. Kurt Wegener¹⁾ on Spitsbergen (base 7 kilometers) and by Dr. Vegard and Krogness in Finmarken (base Haldde—Bossekop 12,6 km). An account of Dr. Wegener's expedition will be found printed in »Schriften der Wissenschaftlichen Gesellschaft in Strassburg, 21 Heft, 1914«. An account of Vegard and Krogness' Aurora measurements was published in the Videnskabsselskabets Skrifter for 1914²⁾.

§ 2. The Expedition: Preparation and Equipment.

In the account of the expedition of 1910 I concluded by suggesting a number of improvements for future expeditions. Such improvements were carried out as regards the expedition of 1913 on the basis of the experiences gained in 1910. A detailed account of these will be given in the following:

Photographic apparatus.

In order to make sure that the time was observed for each Aurora photograph, an improvement was introduced by photographing on the plate a picture of the illuminated watch, simultaneously with that of the Aurora. We could then subsequently at our leisure read the time, and obtain the time of exposure from the sector described by the second hand, or in the case of longer exposures by the minute hand. I employed this improvement as early as during the winter of 1910—1911 whilst photographing the Aurora at Christiania. The electric lamps for illuminating the watch, however, were in the case of the expedition of 1913 replaced by oil lamps protected against the wind by a tin case, for electric batteries proved to be unreliable in the cold. As our objective in the cameras we used that employed in 1910, the extremely luminous cinematograph lens Ernemann Kinostigmat, with an aperture of 25 mm. and focal length of 50 mm.

Cinematograph and prism objective arrangement.

The attempts that were made in 1910 to photograph the Aurora on a cinema film failed because the film employed was not sufficiently sensitive. In the meantime, Lumière et Fils succeeded in producing a new film of extreme sensitiveness. Experiments which I made with the latter showed that it was just as sensitive as the plates we had taken with us. I therefore decided to repeat the trials, and in that connection procured from Ernemann of Dresden a complete cinematograph equipment for taking the pictures. As will be mentioned later on, we succeeded in obtaining a number of cinematograph pictures of the Aurora. In order if possible to get some prism-objective pictures of isolated Aurora rays, I also took with me a prism with an angle of refraction of 60° to place in front of the kinostigmat lens. The selection of the kind of glass to be employed was made after conferring with Dr. Sliper at the Lowell Observatory, Flagstaff, Arizona, during my visit to that place in the summer of 1912. The height of the prism was 40 mm, length of side 80 mm. It was made by Zeiss of Jena, marked 0.3863 v = 35.9 and n = 1.6223. This prism almost doubled the time of exposure.

Slides and shifting boxes.

In order to utilize fully the short time during which the Aurora was revealed in its full glory, we provided ourselves with a large number of slides, of the type employed

¹⁾ Dr. Kurt Wegener: *Das Polarlicht in Spitsbergen nach photogrammetrischen Messungen*, 35 pages with plates.

²⁾ Höhenmessungen des Nordlichts an dem Halddobservatorium von Oktober 1912 bis Anfang Januar 1913, loc. cit. Math. Naturv. klasse 1914, no. 11. See also L. Vegard et Krogness: *Résultats d'observations d'aurores boréales exécutées à l'observatoire de Haldd*, Comptes Rendus Paris, 23 octobre 1916 and Geofysiske Publicationer Bd. 1 No. 1.

in 1910. We took 48 with us, and at Bossekop by the courtesy of the director of the Haldde Observatory, Mr. O. Krogness, we were lent 24 more, so that each station had 36 slides. In addition, I made for each station a shifting box. This was an ordinary wooden case with two round holes in one side. When the lid was shut, plates could be changed in the slides inside the box by inserting one's arms into the holes. This could be done in the open air, so that at the same time we could watch the development of the Aurora and stop the work if it were desirable to take new photographs. The openings for the arms were of black cloth furnished with elastic, so that the cloth fitted tight around the arms and no light entered the box.

Chronometer and watches.

In order to check the time, we had with us a chronometer marked Hohwü No. 639, belonging to the Astronomical Observatory, Christiania. As regards watches for placing in the cameras, we employed at Bossekop a watch belonging to Mr. Birkeland, meteorologist, marked N. W. Noodt, Trondhjem, and at Store Korsnes we used my watch. The latter for the sake of photography was furnished with a black surface which covered half the dial concentrically. The figures over the black surface were painted white, whilst those over the white surface were painted black, and we thereby secured greater chances of successfully photographing the figures.

Telephone arrangement.

In order to have our arms free when we took photographs of the Aurora, I procured bands for the telephone apparatus, so that the receiver could be fastened to the head, and also a breast plate so that the microphone was fastened to the chest by a ribbon around the neck in a similar manner to that employed by telephone operators. Connection with the field telephone apparatus was obtained by means of a wire four metres long.

Plates and development.

As regards plates, after the experiments in Christiania of 1910, we employed partly *Lumière étiquette violette* used on the expedition of 1910, and partly the *ultra rapid* from *Hauff Feuerbach*. They were developed on the spot by myself with the aid of Agfa hydrochinon-methol.

For the sake of completeness and to assist future expeditions I give below a list of articles taken to Bossekop and of those subsequently sent to us.

1. Camera with time registration in case, with strap to carry over shoulder. In the case there were also

Shutters	Oil lantern in tin case
Strips of paper	Tissue paper
Wash leather	Screw driver
Handle to camera	Note book and pencil
Wicks for lantern	Lid to opening in front of objective.

2. Stand for camera (1).

3. Camera with time registration in case, with strap to carry over shoulder. In the case there were also:

2 shutting strings	Strips of paper
Oil lantern in tin case	Wash leather
Screw driver	Handle to camera
Wicks for lantern	Watch

4. Stand for camera (3).

5. Light-proof case with 24 slides. In addition the case contained a number of empty boxes, and also chalk and a sponge. For use at Bossekop.
6. Ditto for use at Store Korsnes.
7. Field telephone with microphone and receiver as described above, for use at Bossekop.
8. Ditto for use at Store Korsnes.
9. Chronometer in case lent by the Observatory at Christiania.
10. Pocket spectroscope from John Browning, London, also lent by above.
11. Oil lantern in case for use at Bossekop.
12. Ditto for use at Korsnes.
13. Small magnifying glass for looking at Aurora negatives.
14. Two small collapsible tables.
15. 2 shifting boxes of kind described above.

We had with us the following plates, films, chemicals, etc.

1. Lumière étiquette violette 9×12 cms. in soldered tin boxes.
2. Ultra rapid, Hauff, 9×11 cms. in soldered tin boxes.
3. Developer in tubes (Agfa) (for all plates).
4. Fixing soda for all plates.
5. Measuring glass.
6. 16 empty bottles.
7. 2 knives for opening the soldered tin boxes.

For dark room work we had the following:

1. 2 dark room lanterns with yellow and red glass.
2. Extra cylindrical dark room lanterns.
3. 24 sheets of black paper.
4. 4 tubes of secotine.
5. 2 packets of stearine candles.
6. 3 large enamelled dishes for developing.
7. 4 small porcelain dishes for plates 9×12 cms.
8. Large lacquered wooden dish.
9. 2 glass funnels.
10. 1 enamelled iron funnel.
11. 5 stands for drying plates 9×12 cms.
12. 6 zink vessels for washing plates.
13. 2 porcelain vessels for stand development.
14. 5 glass boxes for fixing plates.
15. 12 sheets filter paper.
16. 2000 envelopes for negatives 9×12 cms.
17. 1 packet of purified cotton.
18. 1 box drawing pins.
19. Oil and petroleum for lanterns.
20. A measuring tape 23 meters long.

General survey of the work of the expedition at Bossekop and Store Korsnes.

As mentioned above, I was also as in 1910 accompanied on this occasion by my assistant, the meteorologist Bernt Johannes Birkeland.

Every evening when the weather was fine we went out, and as a rule continued our work of photographing the Aurora until early next morning. For the use of future expeditions I will give here a short account of the equipment and method of work at each station.

At the Bossekop station we had the following for field work:

Camera	Prism objective	Cinematograph
Slide case containing	36 slides filled with plates	
Field telephone	Pocket spectroscope	
Oil lantern in box	2 electric pocket lamps	
Shifting box	Suitable stock of photographic plates	
In addition an officer's tent, 2 fairly large tables and a number of stools to sit upon.		

At the Store Korsnes station we had:

Camera	Slide case containing 36 slides filled with plates.
Field telephone	Oil lantern in box
2 electric pocket lamps	Shifting box
Suitable stock of photographic plates	

In addition an officer's tent, 2 fairly large tables, and a number of stools to sit upon.

As soon as we had got into the field we established telephone connection between the stations, set up cameras, and placed the receivers on our ears and the microphones on our chests. When the Aurora began to appear we put a slide in the camera, drew out the lid, focussed upon a suitable constellation which we had selected, and were ready to take pictures. In order to judge the time of exposure correctly, I fastened a watch under my cap by means of a safety pin, so that it rested upon my ear, and I could count the seconds during exposure. In general we exposed as long as the Aurora remained quiet. When taking the photographs the conversation between the stations was somewhat as follows:

Bossekop. Focus upon Vega and report when everything is in order.

Korsnes. Everything is in order.

B. Very well, look out.

B. One.

B. Two.

B. Did it go well. That was plate number 17.

K. Everything in order. Plate number 17.

The number was then written with chalk on the back of the slide. When the pictures were taken in rapid succession the slides were laid in order on the table and the conference regarding their numbers was postponed until later. Moreover, the numbers merely serve as a check, for of course the pictures of the watches appeared on the plates. When about twelve plates had been taken at each station we took care to replace them by new ones in order to be well prepared. These changes were quickly effected in the shifting boxes. Whilst changing, we wrote the numbers in pencil on the gelatine side of the plates, an operation that is not difficult after a little practice. The twelve plates were packed in black paper and placed in an empty plate box. On the outside of the latter were written the name of the station, the date and numbers of the plates. The box was then packed in black paper in order that no light should act through any possible hole or cracks.

The following table shows the results of our work. The time is reckoned from 0^h to 24^h, 0^h corresponding to 12 noon:

Date	Time of work		No. of pairs of Aurora photographs
February 28	6 ^h	—14 ^h	14
March 3	6 ^h	—15 ^h	38
4	9 ^h	—14 ^h	23
6	6 ^h	—13 ^h	7
11	5 ^h 30 ^m	—14 ^h	86
14	5 ^h 30 ^m	—15 ^h 30 ^m	81
15	6 ^h	—13 ^h 30 ^m	81
16	7 ^h	—13 ^h	8
17	8 ^h	—13 ^h 30 ^m	14
18	6 ^h	—14 ^h	5
21	7 ^h	—12 ^h 30 ^m	23
22	7 ^h	—14 ^h	20
23	8 ^h	—12 ^h	1
24	9 ^h	—14 ^h	6
28	7 ^h	—15 ^h 30 ^m	5
29	9 ^h 30 ^m	—15 ^h	83
30	6 ^h 30 ^m	—13 ^h 30 ^m	71
April 1	7 ^h 30 ^m	—14 ^h	70

The plates taken were developed at Bossekop as quickly as possible after exposure, and the pairs of photographs were always developed in the same bath.

THE IMPORTANCE OF TAKING AURORA PHOTOGRAPHS FROM A NETWORK OF STATIONS AROUND THE POLAR BASIN IN COLLABORATION WITH ROALD AMUNDSEN'S EXPEDITION

BY

CARL STØRMER.

As was shown in the circular »Geophysical Investigations in the Arctic Regions in Cooperation with Roald Amundsen's Expedition«¹⁾ there will during the years 1920—22 occur an exceptionally favourable opportunity of extending our knowledge of the nature of the aurora borealis.

For this purpose the following stations must be considered very desirable for the study of the aurora borealis:

Yougoksky
Dikson
Franz Josephs Land
Sodankylä
Northern Sweden
Spitsbergen
Tromsø
Kristiania
Jan Mayen
Iceland
Angmagsalik
Godthaab
Thule

and a series of stations along the aurora belt in *Canada*, *Alaska*, and if possible *Siberia*. In this manner a network of stations will be erected along the aurora belt in the same manner as during the Polar year 1882—83, but in the present case the network will be far more dense on the European side, and the study of the aurora has made far more progress both theoretically and practically than in 1882—83.²⁾ The corpuscular theory³⁾, assuming aurora to be caused by electrical corpuscles coming from the sun, has shown itself to be excellent working hypothesis, and by the introduction of photography in the observations of aurora a fully objective and reliable method has been secured. In another paper²⁾ will be seen an account of this photographic method as it was introduced and used on my expeditions in 1910 and 1913. As the exact hour is supposed to be observed for each photograph, the orientation of the aurora on the heavens can be calculated

¹⁾ See this publication p. 5.

²⁾ See: Corpuscular Theory of the Aurora Borealis, *Terr. Magn. and Atm. Et.*, Vol. XXII, No. 1.

³⁾ See this publication p. 19.

exactly from the stars on the same photograph. If the same aurora is photographed simultaneously from two stations connected by telephone, its height and position in space can be calculated, as I mentioned in the reports from 1910 and 1913.

Among the above-mentioned stations, Sodankylä, Spitsbergen, Tromsø and Kristiania are secured for double photographs of aurora, giving height and situation, and probably the same is the case as regards the station Godthaab an North Sweden. It is to be hoped that as many as possible of the other stations will erect such a base with simultaneous double photography of the aurora.

Let us for the sake of simplicity call stations with double photography of aurora »stations A«, and those where only single photographs can be taken, »stations B«.

At all these stations aurora photographs should as far as possible be taken continuously on fixed days, in order to get as completely as possible *simultaneous records* of the aurora displays around the Polar basin.

On other days the following programmes should be followed:

At stations A, good double photographs of characteristic aurora forms are important for determinations of height and situation in space, and especially for exact determination of lower and upper limits in the atmosphere, and of the situation of long arcs and bands. At stations B, photographs of arcs and bands of long extent, especially their summits and ends near the horizon. Further, photographs of aurora corona for determination of the point of radiation. Also photographs of every characteristic aurora form.

At stations A and B notes on the colours, spectrum, intensity, motion, and general appearance of the aurora are very desirable. Exact hours of each observation very important. If possible photographs to be taken 7 am, 1 pm, 7 pm Greenwich.

Materials can then be collected from the above-mentioned network of stations for the answering of the following important questions:

A. As to the vertical extension of aurora borealis: Is the vertical extension of the different aurora types the same at all places, or is it variable with the geographical position of the place? Especially as regards the lower limits of the auroral curtains, are these the same everywhere as they would appear to be from photographic observations in Spitsbergen, Finmarken and at Kristiania? On the other side, is the height of the upper parts of auroral rays the same everywhere or not? At Kristiania it was much greater in 1916—1918 than in Finmarken in 1910 and 1913.

For the theory of the nature of the aurora, the determination of the lower limits of curtains is of special importance. The determination of the upper limits of aurora rays is also of importance for the question of the upper limits of the atmosphere, and of its constitution.

B. As to the horizontal extension of the aurora borealis:

The long arcs which are often seen at the beginning of the auroral displays, how far do they extend? — If the height is about 100 km., the photographic determination of its summit and the two ends near the horizon, from a series of stations about 1000 to 1500 km. apart long the auroral belt, will give very important information.

C. As to the time of occurrence of special forms of aurora at the different stations:

It will be of great interest to know if the formation of curtains takes place simultaneously or successively at the different stations. The same question applies to coruscations and other special forms. Observations from the Antarctic will here be of great interest as a supplement to those from the Arctic.

D. The exact determination of the point of radiation of the corona streamers,

with simultaneous determination of the direction of the magnetic force of the place, will give important contributions to the question of the physical nature of the aurora.

If it is possible by simultaneous photographs from two stations to determine the shape of the corona streamers (to decide for instance whether they are straight or curved) this will also give important information.

E. Exact determination of the spectral lines of aurora and of the distribution of colours and intensity along aurora rays is another very important subject for study that could perhaps be undertaken at some of the best equipped stations.

*Aphandlinger som ønskes oplæst i »Geofysiske Publikationer« bedes sendt til direktør dr.
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